Review of Boggomoss Snail Populations

Technical Report to the Queensland Coordinator-General's Office, Department of State Development, Infrastructure and Planning

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Technical Summary

This independent review reports on six surveys undertaken for the Boggomoss Snail in the Dawson River valley between 2009 and 2013. Sunwater commissioned five of these and Biodiversity Assessment And Management Pty Ltd (BAAM) performed an independent survey in 2012. Whilst this brief was commissioned to assess the estimates of population sizes provided in the reports, the primary aim of the Sunwater surveys has been to find the Boggomoss Snail when it occurs and increase knowledge of its geographical distribution. Population size estimates have then been attempted secondarily to several of the surveys and a major finding of this review is that all historical population estimates should be disregarded because they were made:

- Using non-representative samples and sampling frames either chosen for another purpose, or not definable, or
- From very small sample sizes.

The Sunwater surveys have added much knowledge about the distribution of the species in the region including:

- The known distribution of the snail in 2013 is far greater than the presumed distribution when the initial recovery plan was put in place in 2008.
- There will probably be more sites containing the snail that have not yet been surveyed
- These sites are most likely located downstream of the proposed dam wall

The Sunwater surveys have highlighted the difficulties in estimating the population numbers of the Boggomoss Snail because:

- The snail is a cryptic species, difficult to detect
- The snail may be less detectable during periods of aestivation than periods of high activity, and;
- Its detection varies with survey technique, timing of the survey, and ambient and recent climatic conditions.

Despite the limitations on the population estimates, we can conclude from the surveys that the snail is most commonly detected in very low densities, and has only ever been recorded in high numbers at two sites, Mt Rose Boggomoss #14 and Nardoo. Even given the difficulty in relation to detectability, when sites have undergone a thorough search effort within a similar sampling period

to other sites (i.e. with similar detectability of snails), an understanding of relative abundance can be gained by assuming density dependent collection. That is, sites with more snails present per unit area should have more snails collected per unit area, thus we can conclude that:

- 22 individuals were collected at Mt Rose Boggomoss #14 in 2009 indicating that the snail was probably in moderate numbers there at that time. But the snails have rarely been collected in 4 surveys since, including only three snails in a census of the site in 2013, suggesting that it is in relatively lower numbers there now. Some of the differences in numbers collected at Mt Rose between years may be because of differences in detectability, from say ambient or antecedent climatic conditions between years, however,
- The snail was in relatively high numbers in Nardoo in 2013 when 125 individuals were collected using approximately one third of the effort used and presumably surveyed in similar conditions to those at Mt Rose in 2013. Thus, differences in detectability alone are unlikely to explain the low numbers at Mt Rose in 2013.

The rest of this report provides a technical review of the contents and methodologies as described within each of the survey reports.

Boggomoss Snail Survey Reports Reviewed:

BAAM (2009) “Nathan Dam, Taroom. Results of Boggomoss Snail survey”, Report prepared for SunWater Pty Ltd. Biodiversity Assessment and Management Pty Ltd.

SKM (2009) “Nathan Dam Project. Survey for the Boggomoss Snail”. Sinclair Knight Merz Pty Ltd.

JKR (2011). “Nathan Dam Project. Survey for the Boggomoss Snail”, Report prepared for SKM Pty Ltd. JKR Ecological Pty Ltd.

BAAM (2012) “Report on the population status of the critically endangered Boggomoss Snail at Mt Rose Station and the Isla-Delusion camping reserve”.

ESM (2012) “ Nathan Dam and Pipelines Project. Results of surveys for Boggomoss snail”, Report prepared for SKM Pty Ltd. Ecological Survey and Management.

AMEC (2013) “ Targeted surveys for the Boggomoss Snail (*Adclarkia dawsonensis*).

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Glossary

Term used	Context for this report
Absolute Abundance	This is the actual *population* size, the total number of animals in the *population*. It is seldom known unless a *census* is performed, and is usually just estimated using a *sample*.
Aestivation	A state of inactivity/dormancy (similar to hibernation) that animals enter generally in response to arid or dry conditions.
Ambient Conditions	Local climatic conditions at the time of sampling. E.g. temperature, precipitation, humidity, cloud cover.
Bias	When an estimate systematically under or over estimates the actual parameter (eg. the *population* abundance) being estimated.
Census	When the entire *population* is surveyed.
Confidence Intervals	A range within which we can be confident the truth exists. For example, we may suggest that we are confident the true number of animals in a *population* is somewhere between 100 and 400.
CPUE (Catch Per Unit Effort)	Required when comparing abundances between different samples unless the effort is identical.
Density Dependent Detection	A species is assumed to be more likely to be detected when there are more individuals present in the site.
Detection	The recording of the occurrence of the snail in a site.
Detectability	The chances of a snail being detected when it occurs (is a probability that ranges between 0 and 1). Detectability close to 1 represents very conspicuous and close to 0 represents very difficult to detect. Can only be determined using repeat visits to the same sites and can be adjusted, according to sample specific factors such as *ambient conditions*.
Distribution	The geographical range in which the species occurs.
Gregarious	The tendency to occur in groups, the opposite of solitary.
Naïve Occupancy	Naïve occupancy is simply the proportion of samples (sites) that the species was detected in.
Patch	Generally refers to the 'patch' of habitat that was sampled
Population (statistical)	The extent of PSUs available for the study. Can refer to habitats within a sampling site, or larger sites within say, a catchment.
Population (biological)	The number of organisms in the survey area. Can refer to within a study site or within the distribution of the species.
Population Density	Number of organisms per unit area. Eg. Snails/ha.
Population Estimate	The estimate of the total number of animals in the *population*.
Potential Habitat	An area of habitat that is deemed suitable for the organism to occur in.
Presence	When a snail is present at a site, whether detected or not.
PSU (Primary Sampling Unit)	Where the samples are taken. Generally the sampling site, but may also refer to a habitat within a site. It is essential that the PSU is explicit (well defined) before any population estimate can be made using a *density* approach to *population* estimation.
Quadrat	A spatial unit used to define a local survey area.

Glossary (cont.)

Term used	Context for this report
Relative Abundance	A comparison of the number of organisms between locations that may not have equal or comparable sampling effort.
Relative Density	As per relative abundance, but using a spatial reference. E.g. number of organisms/ha.
Representative Patch (Statistical)	A patch selected from the *sampling frame* that is selected in a way that makes it *unbiased*.
Sampling Frame	The portion of the population (*PSUs*) that had a (known) chance of being sampled.
Sampling Method	The technique used to conduct the surveys. E.g. raking, turning logs, etc.
Samples	The measurements taken for each *PSU*. E.g. the *transects* may be the *PSUs* in some surveys and the number of snails per transect are the measurement. The number of transects is then the sample size.
Sample Size	The number of *PSUs* in the *sample*.
Site Selection	Refers to how the sites were selected for *sampling*. E.g. from a map or from historical knowledge, etc.
Spatial Distribution	A map of the *populations* of the organism, can include abundances.
Spatial Effort	A map of where the surveys were performed, including effort.
Transect	A sampling unit of a known and repeatable size. Usually consists of a number of *quadrats*.
True Occupancy	True *occupancy* is the proportion of the *sampling frame* that the species occurs in, whether or not it was detected. That is, true occupancy is adjusted for detectability.
Type Location	Refers to the geographical location that the taxonomic specimen to which the taxonomic name for a species is attached. The location the 'type specimen' was collected from.
Unbiased	A *sample* that does not systematically under or overestimate the true *population* parameter being estimated. Almost all samples are biased, but usually the *bias* is random. E.g. random selection of transects is an unbiased method. But it is likely that the estimates made from the measurements will be either under or over estimates of the truth. However, repeating the random sampling method will not return the *same bias* to the next *sample*.

1 Overview of Boggomoss snail surveys undertaken between 2009 – 2013

This section tabulates the stated purpose and methodology used in each of the Boggomoss snail surveys undertaken by various parties between 2009 - 2013. Each of these studies is evaluated in subsequent chapters.

Table 1. Stated Purpose Sampling Methodology and Site Selection of the Boggomoss Snail Studies,- 2009 - 2013

Study	Stated Purpose	Sampling Frame	Site selection	Sampling Methods within sites
BAAM 2009	To quantify two existing populations and locate any additional populations of the Boggomoss Snail within the Dawson River Valley	The environs of the Dawson River between Taroom and Theodore	No description of how sites were selected	• No description of how sampling area was selected. • Targeting of habitat. • Spatial effort unknown (area surveyed not quantified)
SKM 2009	Information on the spatial distribution and population size of the Boggomoss Snail within the Dawson River catchment	Remnant native vegetation in land zone 3 (As described in the EPA regional bioregional ecosystems of 1999) within an 80 km radius of Taroom township and within tenures such as National Parks, State Forests, Forest Reserves, local Council reserves and camping and stock route reserves	Not explicit in the report.	• An initial 100m transect per site, positioning not described. • Additional transect subsequently placed if a snail found in first transect
JKR 2010	Further information on the Boggomoss Snail's distribution, population estimates and identification of potential translocation sites	Mapped as per SKM(2009)	• Selected sites that had not been subject to previous surveys, and which contained apparently dense vegetation and/or ephemeral or permanent wetlands or mound springs. • Could potentially be same patch but different site to previous studies	• Sites sampled in an ad-hoc fashion with emphasis on moister habitats. • Transect subsequently placed if a snail found in first transect. • Acknowledges that the sampling method is different to the BAAM (2009) method

Study	Stated Purpose	Sampling Frame	Site selection	Sampling Methods within sites
ESM 2012	• Testing a number of field sampling methods and subsequent approaches to estimating population size • Providing a population estimate for the species at Mt Rose Station site using methods consistent with that used at other sites • Surveying potential habitat in an effort to locate new populations. • Assessing the physical impact of recent flood events (2010, 2011) on the known habitat of the species.	Included (some of the) sites that had recorded snails in previous surveys	Not defined, but some were included because they were known historically to contain the snail	Not defined, but presumed to target the snail
BAAM 2012	Survey of the Boggomoss Snail	Mt Rose Station and the Isla-Delusion camping reserve on the Dawson River	Only some of the known (historical) sites were selected	• Targeting of leaf litter under trees, under bark, and raking of top soil. • Fallen logs not sampled
AMEC 2013	The presence or absence of the Boggomoss Snail	• Mt Rose Station was described as a census. • Previously identified major habitat patches downstream from the proposed Nathan Dam	Previously identified as major habitat	Targeted sampling within sites to achieve the greatest probability of finding the species if it was present

2 Précis of each Boggomoss Snail survey undertaken between 2009 - 2013

This chapter reviews how well the survey methodologies used relate to the stated purpose of each study, the appropriateness of any analyses that were performed, and an evaluation of the results. A specific evaluation of how each report interpreted the results is given in Table 4.

Table 2. Summary of Boggomoss Snail Survey Activities - 2009 – 2013

Study	BAAM (2008)
Stated Purpose	• To quantify the two existing Boggomoss Snail populations and to identify more sites.
Field Methodology Used	• The survey methods varied between sites –i.e. targeted at Mt Rose and non-random transects in other sites. • Effort was recorded as person hours spent searching. • There is no description of how the habitats were selected or how the transects were placed within each site • The trees at Mt Rose were "located on or at the edge of the boggomoss". The sampling frame therefore cannot be assumed to be representative of the population in a way to allow a density based estimate of population size. That is, it is not explicit that all trees had a chance of being included in the habitats that were sampled. Yet they were used in the extrapolation of snail numbers (see notes in analyses section below).
Précis	• Quantification of the populations cannot be made because the proportion of the population being sampled is not known. There was a spatial proportion of the population inferred *after* sampling, that is, after six habitats were sampled, the results were then applied to 122 trees. • In the report the survey team state "conditions for snail collecting were excellent". • Population estimates would be further compromised because the survey team knowingly did not search microhabitats (logs) that probably contained the snails. That is, some sections of the population (any snails under logs) were deliberately excluded from the sampling frame.
Statistical Analyses	• The four (tree) habitats measured had an average of 3.66 live snails each which was used to estimate a total population of > 350 individuals based on mapping of trees . • This population estimate does not stand up to scrutiny because the trees were mapped after they were sampled. This means that not all trees had a known chance of being sampled prior to the initial samples. That is, the 122 trees are not described as "located on or at the edge of the boggomoss" as the initial sampled trees were. • Furthermore, a total of only six microhabitats were sampled at the Mt Rose site which appear to have been selectively targeted to detect the snail, not to be representative of the population to which the estimate was later applied.
My Summary	• The population estimate findings included juvenile snails but we do not know juvenile survival rates. That is, the population estimate used assumes that juveniles and adults are equally likely to survive in the population. This seems extremely unlikely, given that no adults were collected in this survey. If this

assumption is untrue the estimate is invalid.

- Adult snails were not collected – probably because of a bias in the sampling methodology as described by the comment "The lack of live adults in the samples is most probably due to the fact that this size cohort prefers sheltering under the large logs which are strewn over the Boggomoss. This microhabitat was not searched in order to minimise disturbance of the site".
- The discussion suggests that fallen timber is important habitat for the species, even though the methods clearly stated that fallen timber was not surveyed. Hence, this suggestion is not quantified.
- There were at least 22 juvenile and sub-adult snails on Mt Rose Boggomoss #14 site.
- Assuming that effort and detectability are equivalent between sites within this survey (whilst survey dates of each site are different, they were close together) then there were probably more snails at Mt Rose than the other sites sampled in this survey.
- Detectability of the snails overall for this study may be very low given that, after 3 and 4 snails were detected initially at Mt Rose Boggomoss sites #15 and #16 respectively, no snails were detected at these sites during a second survey period.
- An estimate of the size of the population of Boggomoss snails at Mt Rose should not be made using the data collected in this survey

Study	SKM (2009)
Stated Purpose	• To locate any additional populations of the Boggomoss Snail throughout the Dawson River catchment, including outside the range of historic search effort and within marginal habitat areas • To provide an estimate of the size of the population within its spatial distribution
Field Methodology Used	• The survey sites were selected from potentially suitable habitats based on previous studies and vegetation classification maps of the area. • Within selected sites an initial 100m transect per site was established although the positioning is not described. • If a snail was found, a new transect was placed and included the snail in its first quadrat. • Dead shells were retained by collectors, while live snails were generally returned in situ. • Study was undertaken in the dry season when detectability was thought to be relatively poor. • Two discrete weeks of sampling, a month apart, with potentially different ambient conditions, hence detectability between dates, is not described.
Précis	• The study was set up primarily to find sites containing the snail. • Estimate of population sizes were a secondary aim and could not be adequately performed because of bias in the site selection methodologies (see below). • The population estimates provided are upwardly biased (higher than the true population numbers) because: 1. The initial areas searched were not randomly selected but were aimed at targeting snail detection, hence are more likely to detect a snail or snails than areas that were not sampled. In other words, the areas were not representative of all areas in the site, 2. The transects placed to estimate the densities after the initial snail was detected, included a quadrat with a known snail in it making it non-representative - because quadrats with no snail in them had no chance of being the first quadrat in the transects (even the adjacent quadrats in the transects may not be representative if the species is gregarious), 3. The initial areas searched, where no snails were collected, were not recorded and were not included in the analyses. Hence, the density estimates are based on a much smaller area than was actually searched.
Statistical Analyses	• The population analyses, presented in the final report are upwardly biased (see above). • The population estimates are not suitable for meeting the study's stated purpose because the samples were not representative of the population being estimated.
My Summary	• Population abundance estimates should not be made using the data collected in this survey because the sampling methods are not appropriate for that purpose. • Of the 106 sites sampled, if it could be identified which of those were selected randomly (n) *and* used a standard effort, then the occurrence of snails in x/n sites would provide an estimate of snail occupancy (that is frequency of occurrence, not to be confused with population size) within the sampling frame.

Study	JKR (2010)
Stated Purpose	• To locate any additional populations of the Boggomoss Snail throughout the Dawson River catchment, including outside the range of historic search effort and within areas considered to represent marginal habitat • To discuss previous estimates of the size of the population within its distribution • To make comparison between the methodologies employed by BAAM (2009) and SKM (2009) • To provide population estimates for newly discovered Boggomoss Snail sub-populations.

Field Methodology Used	• Sites were targeted to include:
	  • Areas within the inundation area which support mound springs but which had not been formerly targeted;
	  • Ephemeral wetlands within and outside the inundation area of the proposed Nathan Dam which had not been targeted in previous surveys
	  • Riparian and alluvial habitats downstream of Theodore on the Dawson River;
	  • Riparian and alluvial habitats on tributaries of the Dawson River, both upstream and downstream of the proposed Nathan Dam.
	• Within site effort varied because of differences in the availability of suitable microhabitats for the snail.
	• Sites with abundant leaf litter and debris were searched for longer than those sites with little or no available microhabitat.

Précis	• The habitat patch size was measured after finding snails, and used for estimating populations.
	• The sampling strategy was not designed for estimating populations at the sites because the patches:
	  • are not representative of the site – habitat patches that did not contain the snail were not measured and included in the analyses, and
	  • patches were sampled in a way that leads to biased estimates (as per SKM 2009 methods).

Statistical Analyses	• The population analyses, published in the final report are all upwardly biased (as per SKM 2009 methods). • The population estimates are not suitable because the sampling procedures were not representative (as per the three points given in the précis for SKM 2009 methods above).
My Summary	• The results found snails in new sites and thus document that the distribution of the species is greater than previously thought. However, they also demonstrate that the boundaries of the distribution were still not known because the southern limit of the distribution has not been accurately described. • Collection of the snails in 2/25 random sites is an *estimate* of its naïve occupancy within the sampling frame. That is, the snail occurred in 8% of sites within the sampling frame and this can be a guide to the overall occupancy of the snail in the region defined by the four dot points in the sampling methods above. Occupancy is an independent parameter to population size.

Study	ESM (2012)
Stated Purpose	• Provide a population estimate for the Boggomoss Snail species at Mt Rose Station using methods consistent with that used at other sites • Survey potential Boggomoss Snail habitat in an effort to locate new populations
Field Methodology Used	• Methods show a bias was used in selecting where to make the density estimates. Specifically, the report states that "transects were established within patches of habitat known to support live snails (that is, where a live snail was recorded via targeted active searching)".
Précis	• The formula given for calculating population size as noted in the report is not valid because: 1. the area covered by the sample is not representative of the total area used in the calculations, and 2. the snail habitats were targeted, as described in the methods. • Survey methods included a trial run of a randomised approach, to allow better estimations of the population sizes. • The random approach was not random as only patches that were already known to contain snails were selected for the sampling process. • Estimates therefore are an over-estimate of population density because patches where snails were not detected are not included in the analysis, thus the areas used in the calculations are incorrect.
Statistical Analyses	• The analysis using the random quadrat data is not appropriate because the non-snail patches are not included in the density estimates, thus the areas used are incorrect.
My Summary	• Ambient conditions were deemed suitable for snail collecting. Therefore, if it is assumed that differences in snail detectability between this survey and previous ones are not great, or, at least not worse than previously, I agree that there were less snails present during this survey than during previous surveys in some of the sites. This conclusion can be drawn on the basis that the sites were sampled with effort equivalent to historical surveys. • Sampling procedures were not appropriate for population estimates because of the targeted approach to placing transects. • However, estimating population abundances is not practical given the results, where so few snails were found.

Study	BAAM (2012)
Stated Purpose	Survey of the Boggomoss Snail
Field Methodology Used	• Sampled in dry period (April 2012) – previously described as not conducive to snail collecting. • Similar methods to BAAM (2009), however the proportion of habitat sampled is not described. • Searches involved looking in leaf litter at the base of sandpaper figs and eucalypt trees, under the bark of standing trees, around fallen timber and the top layer of soil was also raked to check for buried snails. • Shady and moist microhabitats on the underside and inside fallen logs proved inaccessible to observation during the search and were not physically searched. • Total search hours used are less than the 2008 report. This may be because of changed habitat extent at the site.
Précis	• No comparisons should be made with historical population numbers because: 1. the proportion of habitat sampled each time is not known, making a density based estimation invalid; 2. different ambient conditions are listed as a probable explanation for differences in collections, and differences in detectability between surveys was not quantified; 3. the2008 survey deliberately biased sampling against adult snails and therefore could not make realistic population estimates. • The report's comment that the lack of live snails could be because they would be aestivating under fallen logs is pure speculation. This comment was made even though none of the studies have reported collecting snails from under logs. Searching under or within *some* logs to confirm this hypothesis during this survey would have been justified given there were no live snails collected at all. • Although considered likely that live snails would be found in the fallen tree microhabitats, because of the destructive collection methods, these areas were not searched. • 80 dead shells (adult and sub-adult) were collected at Mt Rose which was taken to indicate that a viable population still existed on the boggomoss, albeit in aestivation.
Statistical Analyses	None attempted.
My Summary	• The statement about a viable population on Mt Rose Station being in aestivation could have been confirmed by performing a follow up survey. • The suggestion that the 'major population of Boggomoss Snails resides on the Mt Rose station' is not in agreement with the data. That is, in this study no live snails were collected at the Mt Rose Station site and the majority of known populations in other sites were not surveyed.

Study	AMEC (2013)
Stated Purpose	• Determine the presence or absence of the Boggomoss Snail at the Mt Rose site (specifically Boggomoss # 14, 15 and 16). • Determine the presence or absence of the Boggomoss Snail at the previously identified major habitat patches downstream from the proposed Nathan Dam. • Interpret the effect of floods. • Assess habitat suitability. • Identify any apparent threats.
Field Methodology Used	• At Mt Rose, there was a focus on Boggomosses #14, 15 and 16, with six mound springs intensively searched. • These sites were selected after being assessed as exhibiting the correct vegetation type and microhabitat features to support the snail. • All habitats in these sites were searched in total (considered a census within each site). • Intensive surveys of suitable microhabitat within the sites downstream of the Nathan Dam (i.e. census within the patch). • The size of the patch surveyed was documented in all sites. • By making across site comparisons, the report is inferring that detectability was the same across the sites. • It is not clear whether shells were recorded in all sites, but probably were, because 3 dead sub-adults were recorded at Nardoo. This is important for comparing across surveys, because the studies by BAAM are known to record shells. • At the downstream sites, "Habitat patches were selected on the basis that they ….. were likely to support the Boggomoss Snail". This is important because; ○ it must therefore be assumed that the logs at the Mt Rose station site were sampled in this study. This is not testing the BAAM(2012) hypothesis about the logs however, because in this study the snails were thought to be active, not aestivating.
Précis	• As described in section 2.3.1 of the report, much of the total area of the sites (as given in table 3.4) was not part of the sampling frame, so had no chance of being sampled. As a result these areas should not be used in the extrapolation of population estimates. • The surveys conducted at the Mt Rose Station site include the site where BAAM (2012) previously found 80 shells (the historical Mt Rose Boggomoss #14). This survey collected no shells in that site. • Because comparisons in catch rates are made between the sites, the authors have inferred that detectability was equivalent across sites within this study. It is noted that the surveys were over 10 days within a 5 week period (18 March – 25th April) and this time range my have given different ambient conditions (and therefore possible differences in detectability) across some of the surveys. However the authors would have considered this before making the comparisons between the sites and we must therefore presume similar detectability across sites in this survey. • Using different total effort in different sites is fine when the area being surveyed is known. • It is noted that the search effort was considered equivalent within different habitats.

Statistical Analyses	• The extrapolations made using the numbers in Table 3.7 are not valid because:
	  • the selection of patches to survey was clearly biased to favour finding snails,
	  • samples from these patches were therefore not from the total area for each site used in the calculations and given in Table 3.7,
	  • "Snails per hectare numbers" recorded are therefore actually "snails per selected patch hectare",
	• The proportion of available habitat listed in Table 3.4 is incorrect, because much of the area used to calculate the available habitat had no chance of being sampled. That is, they were not considered part of the sampling frame because they were not "… likely to support the Boggomoss Snail".

My Summary	• The 0.2 ha sampled is not representative of the 55 ha available at Nardoo (see note above about selection of habitat patches), however it is true that the total population size of the species at that site is greater than 125. • If the Mt Rose Station site surveys are a census – all sites and all habitat patches within the sites were sampled, including the BAAM (2012) sites - then I agree with the statement from the final report that states that "….just three adult Boggomoss Snails were found at Mt Rose in a single patch of habitat of approximately 1 ha. Given the search intensity undertaken across the entire area of available habitat at the Mt Rose site, it can be concluded that the population is extremely small". • This survey adds value to the understanding of the snail by documenting the numbers of each microhabitat available in each site.

3 Analysis of results from Boggomoss Snail surveys 2009 -2013

Table 3. Analysis and application of results from Boggomoss Snail Field Surveys - 2009 – 2013.

Study	Assessment of survey methods	Constraints arising from survey methods	Population Estimate Errors
BAAM 2009	• This study does not have a well-defined sampling frame. • The methodology uses sampling designed to select sites deemed likely to contain snails, which is appropriate for determining snail presence, but not for population estimates. • Has a known bias against sampling adult snails.	• Actual area sampled is not defined, hence a spatial extrapolation of snail densities should not be used. • The trees sampled are described as "on or at the edge of the Boggomoss", but there is no transparent description of how they were selected.	• The extrapolation appears to use targeted sample results to parts of the population that were not part of the sampling frame. • Does not include adult snails in the population estimates. • Assumes juvenile snails have the same survival rates as adult snails. • Population estimates should not be made.
SKM 2009	• The way the sites were selected is not clear. • Method for locating the initial 100m transect per site is not described. That is, the sampling frame is not clearly defined.	• A biased transect placed if a snail found in the first transect. • Areas searched without finding snails are not quantified and should have been included in population estimates.	• Population estimates are not possible because: – the density estimates were biased by the exclusion of areas searched unsuccessfully, – some areas were deliberately not searched, and, – the secondary transects were placed to include a snail. • Population estimates should not be made.
JKR 2010	Sites were sampled in an ad-hoc fashion with emphasis on moister habitats.	• Biased placement of transect after a snail is found. • Areas searched without finding snails were not quantified and should have been included in population estimates.	• Population estimates are not possible because: – the density estimates were biased by the exclusion of areas searched unsuccessfully, – some areas were deliberately not searched, and, – the secondary

			transects were placed to include a snail. • Population estimates should not be made.
ESM 2012	This survey was aimed at snail detection after significant flooding	• Small sample sizes do not allow population estimates.	• None made.
BAAM 2012	This study has no defined sampling frame. Uses a known bias against sampling adult snails.	• The actual area sampled is not defined. • Conditions for snail collecting are described as poor (dry).	• Population estimates should not be made. • A statement suggesting "the relative importance of the Mt Rose population" was made without collecting any live snails and without attempting to sample other known populations.
AMEC 2013	The within site surveys are designed for maximising detection of the snails.	• Patches sampled do not represent the areas used in the calculations, except Mt Rose Station site which was a census.	• None made. • Density estimates were made, but these estimates are restricted to habitat patches that "clearly contained suitable microhabitat elements such as accumulated leaf litter or flood debris and were likely to support the boggomoss snail. " • Population estimates should not be made.

4 Discussion on reported findings from the Boggomoss Snail surveys undertaken between 2009 - 2013

In this section, every comment pertaining to Boggomoss snail detection, distribution or population sizes as they are presented throughout the discussion and results of each report has been addressed. It is noted that the results and findings may have been correct at the time of reporting and knowledge of the snail has improved since in some instances. Hence, comments are based on the findings of the report itself unless otherwise noted.

Table 4. Assessment of key report findings – Boggomoss Snail Surveys – 2009 – 2013

Study	Key Report Findings	Assessment of Findings
BAAM 2009	Mt Rose Station site has a population of at least 350 snails.	**Disagree** Trees used in the extrapolation to the whole site population did not all have a known chance of being sampled, therefore cannot be included in calculations
BAAM 2009	The preferred microhabitat of the species appears to be deep, moist, accumulated litter.	Anecdotal evidence from a snail expert and must be respected
BAAM 2009	Under fallen timber is also a source of living space for the species.	**Agree** Three live sub-adults were found under timber at Isla Delusion Road.
SKM 2009	The revised population estimate of 17,410 Boggomoss Snails across a relatively large number of sites has significant implications for the conservation management of the species.	**Disagree** The population estimates are upwardly biased because of non-representative sampling as described in tables 2 & 3 above.
SKM 2009	The species occurs at a relatively low density across a broader geographic area than previously anticipated ….	**Agreed** Additional populations were located.
SKM 2009	…… and additional stable, breeding populations have been located.	**Agreed** Additional populations have been located, although stability of the population has not been substantiated
SKM 2009	It is also highly likely that further populations exist in suitable habitat that has been identified but not yet surveyed.	**Agreed** **Because so many potential sites had not been surveyed at this time**
SKM 2009	The methodology used by Stanisic (BAAM 2009) to estimate populations at Mt. Rose Station was different to that used here. The Mt Rose estimate should be revised using the same methodology to ensure consistent comparisons.	**Agreed** Methods used were different **Disagree** Both methods are biased and **should not** be used to compare population estimates
JKR 2010	There are breeding sub-populations of	**Agreed**

	the Boggomoss Snail now known from Mt Rose Station, Isla-Delusion Crossing, Southend Station, Kia Ora Station and Gyranda.	This is a summary of accumulated knowledge at the time of the survey
JKR 2010	Based on the discovery of an additional sub-population of Boggomoss Snails at Southend, …... An estimate of 12,036 snails was calculated for this patch.	**Disagreed** These estimates are upwardly biased. The population is smaller than that estimated.
JKR 2010	As a comparative exercise, the lowest density of Boggomoss Snails observed at any site (0.02/m2) was adopted and used to calculate a conservative population estimate (using density × distribution area [31.81ha]) of 7979 snails across all known sub-populations.	**Disagreed** All the estimates available at this time were upwardly biased.
JKR 2010	The macro and microhabitat preferences of the species are broader than those considered historically.	**Agreed** This is another reason to treat previous population estimates cautiously. That is, some of these habitats were not part of previous sampling frames.
BAAM 2012	However in line with the recovery plan of the Boggomoss Snail (Stanisic 2008), the large number of shells collected is to be considered evidence of a living population.	**Disagreed** I could not find any statements in the recovery plan to support this claim
BAAM 2012	The 2009 population estimate for Mt Rose was based on very few individuals and a revised estimate may vary greatly.	**Agreed** The estimates were based on few individuals. A revised estimate should not be made given methods were aimed at detection and are not suitable for population size estimates.
BAAM 2012	The revised population estimate at Mt Rose should be made in moist conditions to be comparable with the 2009 estimate	**Agreed** If the principle of not sampling in the dry periods is adhered to, then this is a given. **Disagreed** The 2009 estimate is biased and should not be used.
BAAM 2012	The lack of dead shells in Nathan Gorge and Isla-Delusion habitats indicates that these riparian zones do not support large populations of the snail.	**Disagreed** This statement assumes that the persistence of snail shells in these habitats is the same as at Mt Rose. However, these are riparian zones and subject to flooding, and in an earlier report, the same authors suggest shells may be absent in riparian zones because of intermittent flooding (BAAM 2009) – not because of population sizes.
BAAM 2012	The large number of dead shells recovered from Mt Rose Boggomoss	**Disagreed** This is speculation. There are no previous

	indicates that a viable population is still extant on the boggomoss, albeit in aestivation.	Boggomoss papers relating dead shells to population sizes.
BAAM 2012	The findings reaffirm the proposition that the major population of the Boggomoss Snail resides on the Mt Rose boggomoss	**Disagreed** The survey did not sample many of the known and unknown populations, hence has no frame of reference to make this inference.
ESM 2012	Surveys were undertaken at five sites from which live snails had been historically recorded but they were found at only one (Isla Delusion). The three mound springs surveyed on Mt Rose Station failed to yield any live snails. Boggomosses 15 and 16 have now been re-surveyed twice since snails were originally found there with no further evidence of their existence being recorded. For these sites the survey effort is considered thorough and given the lack of suitable habitat (as a result of flood impacts; Section 4.4) it is considered that the snail no longer exists here.	**Disagreed** Given we don't know the detectability very well, it would take many more than 2 revisits using standard methodologies to assume it no longer exists in *any* site. Nevertheless, the principle of density dependent detectability suggests that if the snail is there, it is probably in very low numbers.
ESM 2012	The survey effort is considered thorough and given that Dr John Stanisic also failed to find any live snails here(Mt Rose Station) despite 11 hours searching in April 2012, the continued existence of a sustainable population of the species at the site is unlikely.	**Agreed** The statement about a *sustainable* population appears reasonable, but requires clarification of the term sustainable.
ESM 2012	At the observed densities, population estimates for Isla Delusion would be 3600 snails, based on an area of 14.4ha of suitable habitat and 15,000 snails, based on approximately 60 hectares of potentially suitable habitat at Nardoo.	**Disagreed** These are under-estimates because they are based on 40 quadrats instead of 20. However, the confidence intervals are wide (e.g. between 0 and 90,000 snails in Nardoo [my calculations]) and the numbers have no practical value because the number of snails used in the calculations is so low.
ESM 2012	The results of the current survey suggest that the density of Boggomoss Snails has declined markedly at all known sites and this is best represented by declining returns (in terms of live snails recorded per person hour of searching) for search effort.	**Agreed** Even if this survey had lower snail detectability rates (I don't have any reason to think that it would), the principal of density dependent detection would expect more snails to be found if they were present in large numbers.
ESM 2012	No live Boggomoss Snails have been recorded from the Nathan Dam project	**Agreed** Only shells had been collected since 2008.

	area since 2008, and the status of the species in the vicinity of Mt Rose Station requires further intensive investigation to determine whether the species persists at that location.	
AMEC 2013	Given the search intensity undertaken across the entire area of available habitat at the Mt Rose site, it can be concluded that the population is extremely small. *And* given the search effort at Mt Rose during the current survey, it is unlikely that a significant number of snails exist at the site but were not observed during survey.	**Agree** The entire habitat was searched for very few snails to be found. Conditions for detecting snails were thought to be good. This is supported by the data that confirms that many snails were found (that is, snails were detectable) in other sites surveyed within a few weeks of this site.
AMEC 2013	Moreover, the habitat available at Mt Rose is restricted to a single, small and very isolated patch of vegetation surrounding one mound spring. As this population cannot be replenished by populations upstream, the long term probability of extinction of the species at Mt Rose is higher than at other known sites.	**Agreed** The other populations are more likely to remain connected and thus re-populated after any declines in numbers. However that also doesn't mean the Mt Rose population *will* go extinct.
AMEC 2013	The more we look in these downstream areas, the more we find and there remain significant areas of likely suitable habitat within the riparian zone of the Dawson River or anabranches that have never been searched.	**Agreed** There are many sites that have not yet been searched, the naïve occupancy estimates from JKR (2010) suggest tha snail was in about 8% of sites in the "Dawson riparian and alluvial habitats downstream of Theodore on the Dawson River".
AMEC 2013	BAAM (2009) observed no live adults of the Boggomoss Snail in their sample of Mt Rose Boggomoss site 14. The vast majority of records were of juvenile snails, with two sub-adult snails recorded. This may be indicative of very high juvenile and sub-adult mortality or an artefact of sampling bias away from the preferred habitats of adult Boggomoss Snails (although the current study found that all life stages co-occur in the same habitats and microhabitats).	**Agreed** The BAAM studies are problematic in that they deliberately bias sampling away from adults. And it is true that we do not know juvenile and sub-adult mortality rates for any of the populations. **Additional Comment** The basic methods used appear to be the same, involving raking of litter and moving of larger debris, sampling under logs etc., BAAM 2012 and BAAM 2009 didn't survey under logs suggesting it was destructive, and they themselves note this is a bias away from some of the population (that is, adult snails). Thus this AMEC 2013 paragraph also notes the potential bias away from adult snails used by BAAM. The two BAAM surveys did not find many adults at this site, and the SKM/JKR/AMEC surveys don't seem to find many shells.

		Given that BAAM 2012 collected (removed) the [c]80 adult and sub-adult shells they observed, one could expect fewer shells in this study. However BAAM 2012 did not collect "many dead juvenile snails that were observed in the leaf litter". So given that the AMEC 2013 study was described as intensive, one would expect to collect some of these juvenile shells left *in-situ* by BAAM 2012. I presume they may have been washed away. Regardless of these apparent differences in sampling, we can state that there have been low numbers of adult snails at Mt Rose for several years
AMEC 2013	The current study recorded only adult snails (at Mt Rose), suggesting that there has been limited or no recruitment since the last survey or since the floods.	**Agreed** This statement could be accepted given the effort was considered a census. **Additional Comment** However, it is possible that the low numbers of adults may have been indicative of overall poor detection rates, for all snails. Documentation of the ambient conditions and the dates of sampling relative to the conditions and sampling dates at Isla Delusion, Southend and Nardoo where snails of all life stages were readily detected, could strengthen the validity of the statement.
AMEC 2013	The current study found a higher proportion of sub-adult and juvenile snails at Southend and Isla Delusion, suggesting strong recruitment to these populations.	**Agreed** Recruitment in this context is the additions to the population from successful breeding, – indicated by juveniles and survival, - and indicated by progression to sub- adults and then adults. And sub-adults have been recorded in these sites regularly. **Disagreed** This and the historical surveys at these two sites (as included in attachment 1 of the report) have collected very few snails. Hence whether or not the true proportions are higher is not quantifiable. Nevertheless, I agree that recruitment to these populations is ongoing because the presence of sub-adults is somewhat indicative of juvenile survival rates.
AMEC 2013	The findings of this survey also show that there are other more significant populations of the species, all of which are located a significant distance	**Agreed** The data support that a range of size classes were found at multiple downstream sites. The term "more

	downstream of the proposed Nathan Dam area. A range of age classes were observed at multiple patches within three sites; Isla Delusion, Southend and Nardoo.	significant" infers, there are larger population sizes away from Mt Rose.
AMEC 2013	Considering that only a very small portion of the available suitable habitat at Nardoo was searched (0.2 ha of an estimated 55 ha site), it is likely that the total population of the species at this site is much greater	**Agreed** The total population is probably much greater than the number caught in this study. However, the 0.2 Ha surveyed was not representative of the 55 Ha of the site because of the selective sampling method used. Note that the absolute number can't be estimated because the area represented by the 0.2 that was sampled is not quantified.
AMEC 2013	In terms of the total proportion of each site surveyed, Mt. Rose is considered to have been comprehensively sampled, whereas the larger sites largely remain relatively under-sampled.	**Agreed** There was a census carried out at Mt Rose, surveying all suitable habitats. This means the entire site was surveyed. In the other sites, only some selected patches have been surveyed.
SEIS 2013 Chapter 28.1.2.2. PAGE 28-11	The EIS noted that the most important result from the field surveys was that the species was confirmed as being far more widely distributed than first thought.	**Agreed** This is a ***major*** finding of the field surveys. Gaining a better understanding of the distribution was the primary objective for several of the surveys. As stated in the additional information, the objective was to gain "an understanding of how many populations exist and this was the principal purpose of EIS surveys".
SEIS 2013 Chapter 28.1.2.2. PAGE 28-11	The exact size of the population/s was thought of secondary importance to this information on its distribution given the criteria for assessment of significant impacts	**Agreed** The surveys were generally setup to increase knowledge of the distribution.
SEIS 2013 Chapter 28.1.2.2. PAGE 28-13	BAAM (2009), led by Dr Stanisic, used a micro-habitat approach wherein searching took place under certain tree species (Sandpaper Figs), thought by Dr Stanisic to be a determinant of distribution, and the estimate of the density of snails per micro-habitat was multiplied by the number of such habitats at a site. The method was only used at one site, Mt Rose.	**Agreed** This statement is correct but as it has been noted in this report, the trees selected were not shown to be representative of the number of habitats available. Thus the BAAM (2009) estimate of density should not be considered.
SEIS 2013 PAGE 28-14	The submitter referred to the survey methodology employed by SKM and JKR as "sound". That is, the various survey teams were all likely to find the snail if it was present in a quadrat or under the tree being sampled. This	**Agreed** Having teams that are equally likely to detect the snails given the same ambient conditions is an important component if comparing surveys. The density estimates made should be treated with caution

	statement can be supported by a comparison of the density of snails per square metre based on the microhabitat method conducted by BAAM at Mt Rose (366 individuals over 7,500 m2 = 0.05 snails/m2) and that for the various sites examined by SKM and JKR (range 0.02 to 0.30 snails/m2).	because they are all biased, but it is correct that they are similar in magnitude.
SEIS 2013 PAGE 28-14	What this comparison suggests is that the historic density of snails at Mt Rose was not exceptional and is within the range estimated from a number of other sites irrespective of the method used.	**Agreed** That the Mt Rose *density* is not exceptional.
SEIS 2013 pages 28-14 to 28-17	There are many notes regarding the conservative nature of the estimates given over pages 28-14 – 28-17.	The statements and justifications offered about the estimates provided being conservative are all correct. However, all of the estimates are biased anyway and none of the population estimates should be used.
SEIS 2013 Page 28-17	The submitter stated that the survey "reinforced the conclusions drawn from BAAM surveys, viz., that there is a robust but small population on the Mt Rose site." This is not an accurate reflection of the April 2012 survey results. For example, the survey report did not use the word "robust" nor did it actually estimate population size. The report stated that the findings indicate "the likely presence of a viable population" however, as no live snails in any age class were recorded at either Mt Rose or Isla Delusion even the "likely presence" is questionable.	**Agreed** The conclusions made in the BAAM (2012) survey are based on opinion and not reflected by the data.
SEIS 2013 Page 28-17	The survey report (Stanisic, 2012) attributes no live Boggomoss Snails found at any site, to the dry conditions and the aestivation of the snails. No discussion is included to suggest that populations may have changed (declined) or that such a change may be linked to the recent floods. Given the historic recognition of the risks associated with floods and the very large size of the recent floods across suitable habitat, consideration of such events and the subsequent impacts should have been included.	**Agreed** The report in question uses aestivation as an explanation, without supporting evidence, and does not discuss other options.
SEIS 2013	As other aspects of the methodology were appropriate and it was replicated	**Disagreed** This statement refers to the JKR surveys of

PAGE 28-19	at each site, the data from that first quadrat can be removed to produce a more conservative estimate (Table 28-3). Such exclusion could produce an underestimate because a known quadrat which contained a snail is excluded from the estimate	2011, which are biased because transects were located after finding a snail. The estimate made in this report after removing that quadrat is *probably* still biased because the effort spent before finding the first snail is not included, and the searched habitats are not chosen representatively. That is, because the initial search targeted specific microhabitat(s) thought to support the snail, then the subsequent extrapolations (the areas used when estimating the population size) should only include like habitat, but includes all habitat.
SEIS 2013 Page 28-21	…further surveys were conducted in March and April 2013….. An intensive survey of Mt Rose covering almost every possible area of habitat and taking 96 hours of survey effort, found 3 adults snails in flood debris near the highest point on Boggomoss 14, the original site detailed in the Recovery Plan (Stanisic, 2008). No snails were found on the other two boggomosses on which snails were previously recorded despite searching all available micro-habitats. On the basis of survey intensiveness at this site it was considered that the total population at the main site was unlikely to be significantly greater than the number of snails found because essentially the entire potential habitat had been sampled.	**Agreed** It is reasonable to suggest that the total population was not likely to be significantly higher than that detected during the survey period, with the following assumptions: – the survey was a census (entire potential habitat at the site sampled), – snails present were likely to be detected (noting that the survey was outside the October – February period identified as the high activity period by BAAM (2012)), and – snails were not in areas excluded by the 'potential habitat' rule (i.e. based on the judgement of an experienced surveyor, certain areas were not included in the search because they were deemed unlikely habitat).
SEIS 2013 Page 28-21	At Nardoo, 125 live snails were found, being by far the highest number found from any survey of any site since the species was recorded. Only 0.2 ha of habitat was searched at Nardoo from an estimated 55 ha of suitable habitat. Similarly at Isla Delusion 8 snails were found in a 1.27 ha search area from an estimated suitable habitat area of approximately 55 ha. The search area at Southend was 0.244 ha and returned 14 snails within an estimated suitable habitat area of approximately 16.64 ha. The report concluded that the species	**Agreed** The statement "… the species is clearly more abundant at several downstream sites than it is at Mt Rose" is correct, however: – The sampled areas are correct, but the sampled areas are not directly transferrable to the estimated suitable habitat areas. That is, the sampled patches were targeted for snails and thus were not representative of the total areas used in the calculations. Nevertheless, there can be no doubt there were considerably more snails in the

	is clearly more abundant at several downstream sites than it is at Mt Rose.	downstream sites that at Mt Rose, unless: – There was a detectability difference in the sampling methods. Potential reasons for this include; 1) that the habitats are different, and; 2) it may be that one habitat was sampled in March and the other in April and prevailing conditions (and snail detectability) were affected. Any differences in detectability between searched habitats were adequately implied by the earlier statement about all teams having equal ability to detect the snails when present. I also expect that the authors would have noted any potential sampling differences from ambient or antecedent conditions between the surveys. Therefore, I **agree** with the statement.
SEIS 2013 Page 28-21	"The population at Mt Rose exists at a single site and is extremely small."	**Agreed** The term "single site" is speculation relying on detection rates and requires more revisits and surveys before declaring absence at Boggomoss 15 and 16. Additionally, the term "extremely small" is considered appropriate within the context of other populations being larger.
SEIS 2013 Page 28-22	The most downstream live snails have been recorded at the property Kia Ora, approximately 9 km upstream from Theodore and 74 km downstream from the dam. While some sites further downstream have been investigated, the intensity of survey is very low compared to the upstream area so the result may not reflect the full extent of downstream distribution.	**Agreed** The downstream extent has not been determined accurately yet. The upstream extent appears to be well documented.
SEIS 2013 Page 28-28	"The total area of potential habitat for the species has not been estimated but the area within sites of known habitat is estimated as 97.43ha across all sub-populations. The species is very likely to also exist in sections of suitable habitat between sites at which it has been found."	**Agreed** Note that it differentiates between 'potential habitat' and 'area within sites of known habitats'. This is appropriate. This acknowledges that the areas used in the AMEC 2013 report (e.g. 55ha at Nardoo) are the areas "within sites of known habitat", Not the areas of potential habitat. In lay terms, there are 97.43ha of known sites that may contain the snail. But the snail does not necessarily occupy all of the 97ha within these sites the potential habitats that the snail occupies is

		smaller than 97ha.
SEIS 2013 Page 28-32	**Summary and Recommendation** Based on the evidence, SunWater believes the results presented in the EIS and this Supplement constitute the best scientific information available on the species …….	**Agreed** The best *available* information has been used.

5 Summary of main points

All surveys undertaken to date continue to advance knowledge about the Boggomoss Snail as a species. However, there are a number of critical elements that need to be taken into account when considering the findings of the surveys completed to date, either individually or as a whole.

- Abundance estimates provided in each of the reports are flawed because of unsuitable data. Each of the surveys employs a sampling methodology within sites that has been aimed at optimising snail detection. Because of this, none of the surveys have been designed to allow accurate population estimates. The absolute value of the population estimates as they have been presented therefore should not be considered from the reports as they do not represent an accurate picture of snail population numbers

- Comparisons of relative abundance, number of shells, adults, juveniles, etc., per site as a function of survey effort (or time spent searching) should also be treated cautiously. The snails are a cryptic species and there are differences in detection between habitats, sites, dates, search teams and search methods hence a lack of consistency in survey conditions may lead to different findings.

- Conclusions presented when survey teams have found only a few snails should be treated cautiously. In some instances, detectability itself may have contributed to the low numbers. However, when several sites were sampled in the same survey period (hence should have similar snail detectability), then those surveys in which more snail CPUE occurred probably held more snails (within the targeted habitat type). Furthermore, it would be reasonable to suggest that sites where many snails were detected were those sites that had a known potential to hold sizeable populations of snails.

- Surveys that returned a greater numbers of the snails include:
    - Nardoo - patches 1,3,5 and 6 (AMEC 2013)
    - Mt Rose Boggomoss #14 (QLD Museum 1997 and BAAM 2009)

Site size and habitat size

A site consists of a mosaic of patches of suitable habitat. So a site such as the 55ha at Nardoo contains a mosaic of habitat patches suitable for the Boggomoss Snail. Thus the overall 'suitable' habitat area is smaller than 55ha, and could be evaluated by mapping. However, the entire 55ha including the habitat in between 'suitable patches' could possibly be considered as a Boggomoss Snail *site*. Consequently,

- The Nardoo 'suitable' patches sampled were small, 0.022 to 0.067ha each, although patches 5 and 6 are probably one slightly larger patch. These Nardoo 'suitable' patches were

targeted and sampled intensively, however the report suggests that much of the 55ha of the site has potential to hold Boggomoss Snails.

- The Boggomoss #14 site at Mt Rose is quite small, somewhere between 0.75ha (BAAM 2009) AMD 1.024ha (AMEC 2013).

- The Nardoo site is therefore considered the most likely of all historically sampled sites to hold the largest population of the snails.

6 Conclusions

From the work that has been undertaken to date, it can be concluded that:

- The surveys have increased our knowledge of the distribution of the Boggomoss Snail (the geographical range in which it occurs)
- Population sizes (the number of snails) should not be made using the survey data
- The distribution of the snail is greater than what it was assessed as in 2008
- There are probably sites downstream of the proposed dam containing the snail that have not yet been surveyed
- Despite general difficulty in detecting the snails, when sites have been given thorough effort, relative abundances within suitable habitat patches are able to be calculated
- It is likely the snail was in higher numbers at Mt Rose Boggomoss #14 in 2009 than in 2012 or 2013.
- The snail was in high numbers at Nardoo in 2013.

Additional comments

I made these additional notes when reviewing the findings from all snail surveys that that have been undertaken to date. They are outside the scope of the review brief, but may be of interest when future work is being considered.

- The detectability of the snails is known to vary according to ambient conditions, time of year and search methodology used. No attempt to quantify detectability of the snails has been made. Detection rates assist with determining which sites the snail occurred in, therefore, it is likely that the snail was present but not detected in many of the historical surveys. However, when it was present in large numbers, it was detected.
- In the SKM (2009) survey report, it is noted that the snails tend to retreat to moister refuges during dry periods. This would seem an ideal time to use targeted sampling however, several of the other survey reports hypothesise that the snails may be less active in 'very dry' periods (i.e. they may undergo aestivation) and that detectability becomes more difficult. BAAM (2012) speculates that aestivation occurs under fallen logs but this hypothesis is not substantiated anywhere. AMEC (2013) surveyed under logs and may have data that can inform the relative importance of all microhabitats for the species during their surveys, including under logs.
- The AMEC (2013) report quantified microhabitats in several locations. The survey found that at the Mt Rose site, more than 30 per cent of microhabitats were logs. All the other sites had less than 10 per cent of microhabitats as logs. Clearly, Mt Rose has different habitat than the other sites. The detectability of the snails is also almost certainly different in different habitats. This is not a problem for the latest surveys where the entire potential habitat at Mt Rose (including under logs) was surveyed. Undoubtedly, the effort (in terms of hours) required is different in different habitats.
- The detectability of the snails maybe age dependent, with sub-adults and juveniles often caught in much higher numbers than adults.
- Whilst the surveys were designed to detect snails rather than estimate snail population numbers, detectability is density dependant. That is, sites with more snails are more likely to have snails detected. As a matter of principle, sites in which fewer snails were detected using a standard effort will therefore tend to have fewer snails present. Differences in habitat composition also appear to contribute to varying survey effort efficiency between sites. Nevertheless, sites at which more snails were collected for a standard effort probably contained larger populations than sites with fewer snails collected. Using this probability as a basis identifies Mt Rose in 2009 and Nardoo in 2013 as the sites having the largest populations. This is a simplified approach and should not be considered as definitive, rather used for relative comparisons. Differences in CPUE between sites and/or dates may be for various reasons, including detectability, or population size.
- Every study so far has used a targeted strategy aimed at maximising detection of snails. That is, determining occurrence. Population estimates have all been a secondary focus. Every study that has attempted to estimate the population numbers so far has done so using a sampling strategy that targeted detection, and are characterised by the sampling of habitats that were deemed more or most likely to contain snails. All surveys that list a population estimate have included total area estimates that include areas not deemed likely to contain snails, hence were not part of the sampling frame and therefore should not be part of the population estimate.

- Shells are recorded in some studies, but not in others. It is not clear if this is because they aren't reported or because they weren't observed. One study (BAAM 2102) suggests that lots of shells and no live snails indicate a strong population, albeit with poor detection rates. BAAM (2009) suggest that shells may be absent because of intermittent flooding. Another study (SKM 2009) notes that shells alone cannot be used to positively identify the species.
- Detectability may not be the same as in other studies – i.e. until detection of the snail is better quantified, comparing snail occurrences or density estimates across studies is not wise because differences may be from detectability differences. However, because the same Mt Rose Boggomoss site as BAMM (2012) was surveyed and there were no shells recorded in this survey and 80 by BAMM (2012) it is possible that:
  - BAMM kept the shells and didn't leave any behind,
  - the field survey techniques used here do not favour detection or recording of shells,
  - the shells disappeared between surveys, or
  - some other explanation.

  Either way, this difference in shell detections is consistent between the surveys of BAMM and other parties, which suggests that the methods may not necessarily be comparable. This is more reason to not make anything but general comparisons of snail population sizes between these surveys. Absolute population size estimates should definitely be compared between the surveys at Mt Rose station because the initial estimates were biased.

- Several studies claim that many sub-adults and juveniles indicate a strong population, even though the survival rates of these individuals to adults is not known.
- Mt Rose Boggomoss #14 is listed as the type location (BAAM 2009) and has been surveyed many times with varying results. Much of the argument for the importance of the Mt Rose Boggomoss #14 snail population, as stated in the two BAAM reports (2009 and 2012), is based on speculation that the adults were not detected because they were aestivating under logs. The most recent AMEC (2013) survey performed a comprehensive survey, including under logs, and did not find significant numbers of adults or shells there. Complicating this result however, the AMEC (2013) survey was conducted during the March - April period when snails were thought to be aestivating , occurring outside the October – February period when the BAAM reports suggest the adults are more active.

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